Phenomenological Applications of k_T-Factorization –Large Direct CP-Asymmetry in B-meson Decays–

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Abstract

We discuss applications of the perturbative QCD approach in the exclusive non-leptonic two body B-meson decays. We briefly review its ingredients and some important theoretical issues on the factorization approaches. PQCD results are compatible with present experimantal data for the charmless B-meson decays. We predict the possibility of large direct CP asymmetry in $B^0 \to \pi^+\pi^-$ $(23 \pm 7\%)$ and $B^0 \to K^+\pi^-$ $(-17 \pm 5\%)$. We also investigate the Branching ratios, CP asymmetry and isopsin symmetry breaking in $B \to (K^*/\rho)\gamma$ decays and look for the possible new physics contribution via gluino mediation SUSY which can accomodate the large deviation of $S_{\phi K_s}$ from SM.

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I. INTRODUCTION

Understanding nonleptonic B meson decays is crucial for testing the standard model(SM), and also for uncovering the trace of new physics. The simplest case is two-body nonleptonic B meson decays, for which Bauer, Stech and Wirbel proposed the factorization assumption (FA) in their pioneering work [1]. Considerable progress, including the generalized FA [2, 3, 4] and QCD-improved FA (QCDF) [5], has been done since this proposal. On the other hand, technique to analyze hard exclusive hadronic scattering was developed by Brodsky and Lepage [6] based on collinear factorization theorem in perturbative QCD (PQCD). A modified framework based on k_T factorization theorem has been given in [7, 8], and extended to exclusive B meson decays in [9, 10, 11, 12]. The infrared finiteness and gauge invariance of k_T factorization theorem was shown explicitly in [13]. Using this so-called PQCD approach, we have investigated dynamics of nonleptonic B meson decays [14, 15, 16]. Our observations are summarized as follows:

1. FA is approximately correct, as our computation shows that nonfactorizable contributions in charmless B meson decays are negligible.
2. Penguin amplitudes are enhanced, as the PQCD formalism inludes dynamics from the region, where the enegy scale μ runs to $\sqrt{\bar{\Lambda} m_b} < m_b/2$, $\bar{\Lambda} \equiv m_B - m_b$ being the B meson and b quark mass difference.
3. Annihilation diagrams contribute to large short-distance strong phases through $(S+P)(S-P)$ penguin operators.
4. The sign and magnitude of CP asymmetries in two-body nonleptonic B meson decays can be calculated, and we have predicted relatively large CP asymmetries in the $B \to K^{(*)}\pi$ [14, 17] and $\pi\pi$ modes[15, 16, 18].

In this talk we summarize shortly ingredient of PQCD method and important theoretical issues, and show branching ratios of B-meson decays including $B \to K^*\gamma$ decays and possible large direct CP-violation in $B \to \pi\pi$ and $K\pi$ processes. Finally we show a possible solution to explain the large deviation from SM in the indirect CP asymmetry of $B \to \phi K_s$ mode.

II. INGREDIENTS OF PQCD AND THEORETICAL ISSUES

End Point Singularity and Form Factors: If we calculate the $B \to \pi$ form factor $F^{B\pi}$ at large recoil using the Brodsky-Lepage formalism [19, 20], a difficulty immediately occurs. The lowest-order diagram for the hard amplitude is proportional to $1/(x_1 x_3^2)$, x_1 being the momentum fraction associated with the spectator quark on the B meson side. If the pion distribution amplitude vanishes like x_3 as $x_3 \to 0$ (in the leading-twist, *i.e.*, twist-2 case), $F^{B\pi}$ is logarithmically divergent. If the pion distribution amplitude is a constant as $x_3 \to 0$ (in the next-to-leading-twist, *i.e.*, twist-3 case), $F^{B\pi}$ even becomes linearly divergent. These end-point singularities have also appeared in the evaluation of the nonfactorizable and annihilation amplitudes in QCDF.

When we include small parton transverse momenta $k_\perp$, we have

$$\frac{1}{x_1\, x_3^2 M_B^4} \qquad \to \qquad \frac{1}{(x_3\, M_B^2 + k_{3\perp}^2)\ [x_1 x_3\, M_B^2 + (k_{1\perp} - k_{3\perp})^2]} \tag{1}$$

and the end-point singularity is smeared out owing to the Sudakov and threshold resummation effects[14] as shown in figure 1. In PQCD, we can calculate analytically space-like form factors for $B \to P, V$ transition and also time-like form factors for the annihilation process [21, 22].

Strong Phases: While stong phases in FA and QCDF come from the Bander-Silverman-Soni (BSS) mechanism[23] and from the final state interaction (FSI), the dominant strong phase in PQCD come from the factorizable annihilation diagram[14]. In fact, the two sources of strong phases in the FA and QCDF approaches are strongly suppressed by the charm mass threshold and by the end-point behavior of meson wave functions. So the strong phase in QCDF is almost zero without soft-annihilation contributions.

Dynamical Penguin Enhancement vs Chiral Enhancement: The typical hard scale is about 1.5 GeV as discussed in Ref.[14]. Since the RG evolution of the Wilson coefficients $C_{4,6}(t)$ increase drastically as $t < M_B/2$, while that of $C_{1,2}(t)$ remain almost constant, we can get a large enhancement effects from both wilson coefficents and matrix elements in PQCD.

In general the amplitude can be expressed as

$$Amp \sim [a_{1,2}\ \pm\ a_4\ \pm\ m_0^{P,V}(\mu) a_6] \cdot\ < K\pi|O|B > \tag{2}$$

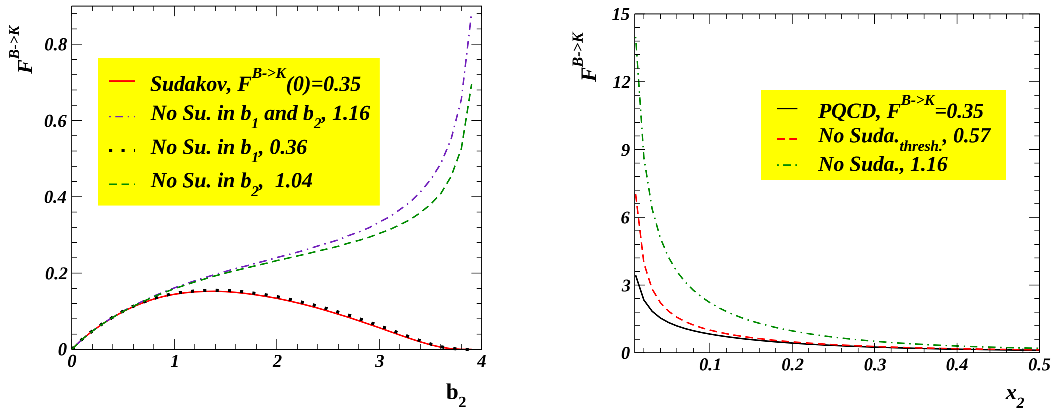


FIG. 1: Sudakov suppression and threshold resummation effects in $B \to K$ transition form factor

with the chiral factors $m_0^P(\mu) = m_P^2/[m_1(\mu) + m_2(\mu)]$ for pseudoscalr meson and $m_0^V = m_V$ for vector meson. To accommodate the $B \to K\pi$ data in the factorization and QCD-factorization approaches, one relies on the chiral enhancement by increasing the mass m_0 to as large values about 3 GeV at $\mu = m_b$ scale. So two methods accomodate large branching ratios of $B \to K\pi$ and it is difficult for us to distinguish two different methods in $B \to PP$ decays. However we can do it in $B \to PV$ because there is no chiral factor in LCDAs of the vector meson.

We can test whether dynamical enhancement or chiral enhancement is responsible for the large $B \to K\pi$ branching ratios by measuring the $B \to VP, VV$ modes. In these modes penguin contributions dominate, such that their branching ratios are insensitive to the variation of the unitarity angle ϕ_3. Our prediction for various modes are shown at Table 2, in fact, which is in a good agreement with experimental data.

Fat Imaginary Penguin in Annihilation: There is a falklore that annihilation contribution is negligible compared to W-emission one. In this reason annihilation contribution was not included in the general factorization approach and the first paper on QCD-factorization by Beneke et al. [25]. In fact there is a suppression effect for the operators with structure $(V-A)(V-A)$ because of a mechanism similar to the helicity suppression for $\pi \to \mu\nu_\mu$. However annihilation from the operators $O_{5,6,7,8}$ with the structure $(S-P)(S+P)$ via Fiertz transformation survive under the helicity suppression and can get large imaginary value. The real part of factorized annihilation contribution becomes small because there is a cancellation between left-handed gluon exchanged one and right-handed gluon exchanged one as shown in Table 1. This mostly pure imaginary value of annihilation is a main source of large CP asymmetry in $B \to \pi^+\pi^-$ and $K^+\pi^-$. In Table 3 we summarize the CP asymmetry in $B \to K(\pi)\pi$ decays.

III. NUMERICAL RESULTS

Branching ratios in Charmless B-decays: The PQCD approach allows us to calculate the amplitudes for charmless B-meson decays in terms of ligh-cone distribution amplitudes upto twist-3. We focus on decays whose branching ratios have already been measured. We take allowed ranges of shape parameter for the B-meson wave funtion as $\omega_B = 0.36-0.44$ which accomodate to reasonable form factors, $F^{B\pi}(0) = 0.27-0.33$ and $F^{BK}(0) = 0.31-0.40$. We use values of chiral factor with $m_0^\pi = 1.3GeV$ and $m_0^K = 1.7GeV$. Finally we obtain branching ratios for $B \to K(\pi)\pi$ [14, 15], $K\phi$ [21, 26] $K^*\phi$[27] and $K^*\pi$[17], which is well agreed with present experimental data.

CP Asymmetry of $B \to \pi\pi, K\pi$: Because we have a large imaginary contribution from factorized annihilation diagrams in PQCD approach, we predict large CP asymmetry ($\sim 25\%$) in $B^0 \to \pi^+\pi^-$ decays and about -15% CP violation effects in $B^0 \to K^+\pi^-$. The detail prediction is given in Table 3. The precise measurement of direct CP asymmetry (both magnitude and sign) is a crucial way to test factorization models which have different sources of strong phases. Our predictions for CP-asymmetry on $B \to K(\pi)\pi$ have a totally opposite sign to those of QCD factorization. Recently it was confirmed as the first evidence of the direct CP-violation in B-decays that the DCP asymmetry in $B \to K^\pm\pi^\mp$ decay is -0.09 ± 0.03 with 3σ deviations from zero, which is in a good agreement with PQCD result[14].

Radiative B-decays ($B \to (K^*/\rho/\omega)\gamma$): Radiative B-meson decays can provide the most reliable window to understand the framework of the Standard Model(SM) and to look for New Physics beyond SM by using the rich

TABLE I: Branching ratios of $B \to \pi\pi, K\pi$and KK decays with $\phi_3 = 80^0$, $R_b = \sqrt{\rho^2+\eta^2} = 0.38$. Here we adopted $m_0^\pi = 1.3$ GeV, $m_0^K = 1.7$ GeV and $0.36 < \omega_B < 0.44$. Unit is 10^{-6}.

Modes	CLEO	BELLE	BABAR	World Av.	PQCD
$\pi^+\pi^-$	$4.5^{+1.4+0.5}_{-1.2-0.4}$	$4.4 \pm 0.6 \pm 0.3$	$4.7 \pm 0.6 \pm 0.2$	4.6 ± 0.4	$5.93 - 10.99$
$\pi^+\pi^0$	$4.6^{+1.8+0.6}_{-1.6-0.7}$	$5.3 \pm 1.3 \pm 0.5$	$5.5^{+1.0}_{-0.9} \pm 0.6$	5.3 ± 0.8	$2.72 - 4.79$
$\pi^0\pi^0$	< 4.4	< 4.4	< 3.6	< 3.6	$0.33 - 0.65$
$K^\pm\pi^\mp$	$18.0^{+2.3+1.2}_{-2.1-0.9}$	$18.5 \pm 1.0 \pm 0.7$	$17.9 \pm 0.9 \pm 0.7$	18.2 ± 0.8	$12.67 - 19.30$
$K^0\pi^\mp$	$18.8^{+3.7+2.1}_{-3.3-1.8}$	$22.0 \pm 1.9 \pm 1.1$	$20.0 \pm 1.6 \pm 1.0$	20.6 ± 1.4	$14.43 - 26.26$
$K^\pm\pi^0$	$12.9^{+2.4+1.2}_{-2.2-1.1}$	$12.8 \pm 1.4^{+1.4}_{-1.0}$	$12.8^{+1.2}_{-1.0} \pm 1.0$	12.8 ± 1.1	$7.87 - 14.21$
$K^0\pi^0$	$12.8^{+4.0+1.7}_{-3.3-1.4}$	$12.6 \pm 2.4 \pm 1.4$	$10.4 \pm 1.5 \pm 1.8$	11.5 ± 1.7	$7.92 - 14.27$
$K^\pm K^\mp$	< 0.8	< 0.7	< 0.6	< 0.6	0.06
$K^\pm \bar{K}^0$	< 3.3	< 3.4	< 2.2	< 2.2	1.4
$K^0 \bar{K}^0$	< 3.3	< 3.2	< 1.6	< 1.6	1.4

TABLE II: Branching ratios of $B \to \phi K^{(*)}$and $K^*\pi$ decays with $\phi_3 = 80^0$, $R_b = \sqrt{\rho^2+\eta^2} = 0.38$. Here we adopted $m_0^\pi = 1.3$ GeV and $m_0^K = 1.7$ GeV. Unit is 10^{-6}.

Modes	CLEO	BELLE	BABAR	World Av.	PQCD
$\phi K^\pm$	$5.5^{+2.1}_{-1.8} \pm 0.6$	$9.4 \pm 1.1 \pm 0.7$	$10.0^{+0.9}_{-0.8} \pm 0.5$	9.3 ± 0.8	$8.1 - 14.1$
ϕK^0	$5.4^{+3.7}_{-2.7} \pm 0.7$	$9.0 \pm 2.2 \pm 0.7$	$7.6^{+1.3}_{-1.2} \pm 0.5$	7.7 ± 1.1	$7.6 - 13.3$
$\phi K^{*\pm}$	$10.6^{+6.4+1.8}_{-4.9-1.6}$	$6.7^{2.1+0.7}_{-1.9-1.0}$	$12.1^{+2.1}_{1.9} \pm 1.1$	9.4 ± 1.6	$12.6 - 21.2$
ϕK^{*0}	$11.5^{+4.5+1.8}_{-3.7-1.7}$	$10.0^{+1.6+0.7}_{-1.5-0.8}$	$11.1^{+1.3}_{-1.2} \pm 0.8$	10.7 ± 1.1	$11.5 - 19.8$
$K^{*0}\pi^\pm$	$7.6^{+3.5}_{-3.0} \pm 1.6$	$19.4^{+4.2+4.1}_{-3.9-7.1}$	$15.5 \pm 3.4 \pm 1.8$	12.3 ± 2.6	$10.2 - 14.6$
$K^{*\pm}\pi^\mp$	$16^{+6}_{-5} \pm 2$	< 30	$-$	16 ± 6	$8.0 - 11.6$
$K^{*+}\pi^0$	< 31	$-$	$-$	< 31	$2.0 - 5.1$
$K^{*0}\pi^0$	< 3.6	< 7	$-$	< 3.6	$1.8 - 4.4$

sample of B-decays.

In contrast to the inclusive radiative B-decays, exclusive processes such as $B \to K^*\gamma$ are much easier to measure in the experiment with a good precision[28]. The main short-distance (SD) contribution to the $B \to K^*\gamma$ decay rate involves the matrix element

$$< K^*\gamma|O_7|B >= \frac{em_b}{8\pi^2}(-2i)\epsilon_\gamma^\mu < K^*|\bar{s}\sigma_{\mu\nu}q^\nu(1-\gamma_5)b|B(p) >, \tag{3}$$

which is parameterized in terms of two invariant form fectors as

$$\begin{aligned} < K^*(P_3,\epsilon_3)|\bar{s}\sigma_{\mu\nu}q^\nu(1-\gamma_5)b|B(P) > \;&=\; [\epsilon_{3,\mu}(q\cdot P) - P_\mu(q\cdot\epsilon_3)]\cdot 2T_2(q^2) \\ &\quad + i\epsilon_{\mu\nu\alpha\beta}\epsilon_3^\nu P^\alpha q^\beta \cdot 2T_1(q^2). \end{aligned} \tag{4}$$

Here P and $P_3 = P - q$ are the B-meson and K^* meson momentum, respectively and ϵ_3 is the polarization vector of the K^* meson. For the real photon emission process the two form factors coincide, $T_1(0) = T_2(0) = T(0)$. This form factor can be calculable in the k_T factorization method including the sudakov suppression factor and the threshold

Direct $A_{CP}(\%)$	BELLE	BABAR	PQCD	QCDF
$\pi^+\pi^-$	$77 \pm 27 \pm 8$	$30 \pm 25 \pm 4$	$16.0 \sim 30.0$	-6 ± 12
$\pi^+\pi^0$	$30 \pm 30^{+6}_{-4}$	$-3 \pm 18 \pm 2$	0.0	0.0
π^+K^-	$-6 \pm 9^{+6}_{-2}$	$-10.2 \pm 5.0 \pm 1.6$	$-12.9 \sim -21.9$	5 ± 9
π^0K^-	$-2 \pm 19 \pm 2$	$-9.0 \pm 9.0 \pm 1.0$	$-10.0 \sim -17.3$	7 ± 9
$\pi^-\bar{K}^0$	$46 \pm 15 \pm 2$	-4.7 ± 13.9	$-0.6 \sim -1.5$	1 ± 1

TABLE III: CP-asymmetry in $B \to K\pi, \pi\pi$ decays with $\phi_3 = 40^0 \sim 90^0$, $R_b = \sqrt{\rho^2+\eta^2} = 0.38$. Here we adopted $m_0^\pi = 1.3$ GeV and $m_0^K = 1.7$ GeV.

Decay Modes	CLEO	BaBar	Belle
$\mathrm{Br}(B \to K^{*0}\gamma)$ (10^{-5})	$4.55 \pm 0.70 \pm 0.34$	$4.23 \pm 0.40 \pm 0.22$	$4.09 \pm 0.21 \pm 0.19$
$\mathrm{Br}(B \to K^{*\pm}\gamma)(10^{-5})$	$3.76 \pm 0.86 \pm 0.28$	$3.83 \pm 0.62 \pm 0.22$	$4.40 \pm 0.33 \pm 0.24$
$\mathrm{Br}(B \to \rho^0\gamma)$ (10^{-6})	< 17	< 1.2	< 2.6
$\mathrm{Br}(B \to \rho^+\gamma)$ (10^{-6})	< 13	< 2.1	< 2.7
$\mathrm{Br}(B \to \omega\gamma)$ (10^{-6})		< 1.0	< 4.4
$\mathcal{A}_{CP}(B \to K^{*0}\gamma)$ (%)	$8 \pm 13 \pm 3$	$-3.5 \pm 9.4 \pm 2.2$	$-6.1 \pm 5.9 \pm 1.8$
$\mathcal{A}_{CP}(B \to K^{*+}\gamma)$ (%)			$+5.3 \pm 8.3 \pm 1.6$

TABLE IV: Experimental measurements of the averaged branching ratios and CP-violating asymmetries of the exclusive $B \to V\gamma$ decays for $V = K^*, \rho$ and ω.

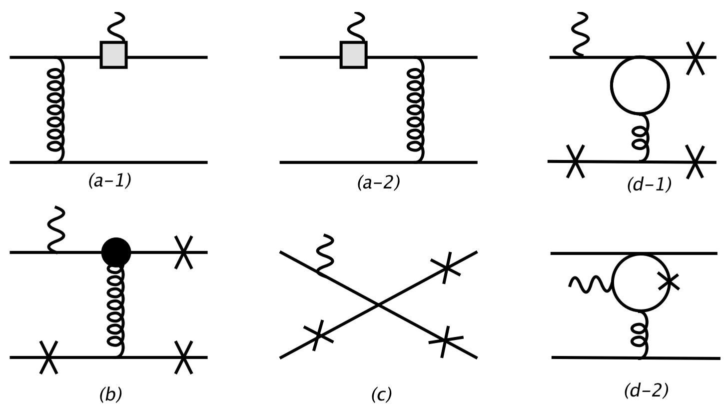


FIG. 2: Feynman diagrams of the magnetic penguin(a), chromomagnetic penguin(b), annihilation(c) and 0_2-penguin contributions for $B \to V\gamma$ decays

resummation effects. As discussed in ref[31], we obtain $T(0) = 0.28 \pm 0.02$ for $B \to K^*\gamma$ which is far away from the QCD result 0.38 ± 0.06 by using the light-cone QCD sum rule [29], however in accordance with the preliminary result of Lattice QCD, 0.25 ± 0.06[30].

Even though theoretical predictions for the exclusive decays always has large model dependent hadronic uncertainties, such uncertainties can be cancelled in the searching of the CP-asymmetry and the isospin breaking effect.

Including all possible contributions from $0_{7\gamma}, 0_{8g}, 0_2$-penguin and annihilation in Figure 2, we obtain the Branching ratios:

- $Br(B^0 \to K^{0*}\gamma) = (3.5^{+1.1}_{-0.8}) \times 10^{-5}$ $\qquad Br(B^+ \to K^{+*}\gamma) = (3.4^{+1.2}_{-0.9}) \times 10^{-5}$,
- $Br(B^0 \to \rho^0\gamma) = (0.95 \pm 0.07) \times 10^{-6}$ $\qquad Br(B^+ \to \rho^+\gamma) = (1.63 \pm 0.20) \times 10^{-6}$,

and the CP-Asymmetry :

- $Acp(B^0 \to K^{0*}\gamma) = (0.39^{+0.06}_{-0.07})\%$ $\qquad Acp(B^+ \to K^{+*}\gamma) = (0.62 \pm 0.13)\%$

The small difference in the branching fraction between $K^{0*}\gamma$ and $K^{+*}\gamma$ can be detected as the isopsin symmetry breaking which tells us the sign of the combination of the Wilson coefficients, C_6/c_7. We obtain

$$\Delta_{0-} = \frac{\eta_\tau Br(B \to \bar{K}^{0*}\gamma) - Br(B \to K^{*-}\gamma)}{\eta_\tau Br(B \to \bar{K}^{0*}\gamma) + Br(B \to K^{*-}\gamma)} = (5.7^{+1.1}_{-1.3} \pm 0.8)\% \tag{5}$$

where $\eta_\tau = \tau_{B^+}/\tau_{B^0}$. The first error term comes from the uncertainty of shape parameter of the B-meson wave function ($0.38 < \omega_B < 0.42$) and the second term is origined from the uncertainty of η_τ. By using the world averaged value of measurement and $\tau_{B^+}/\tau_{B^0} = 1.083 \pm 0.017$, we find numerically that $\Delta_{0-}(K^*\gamma)^{exp} = (3.9 \pm 4.8)\%$. In PQCD we can not expect large isospin symmetry breaking in $B \to K^*\gamma$ system.

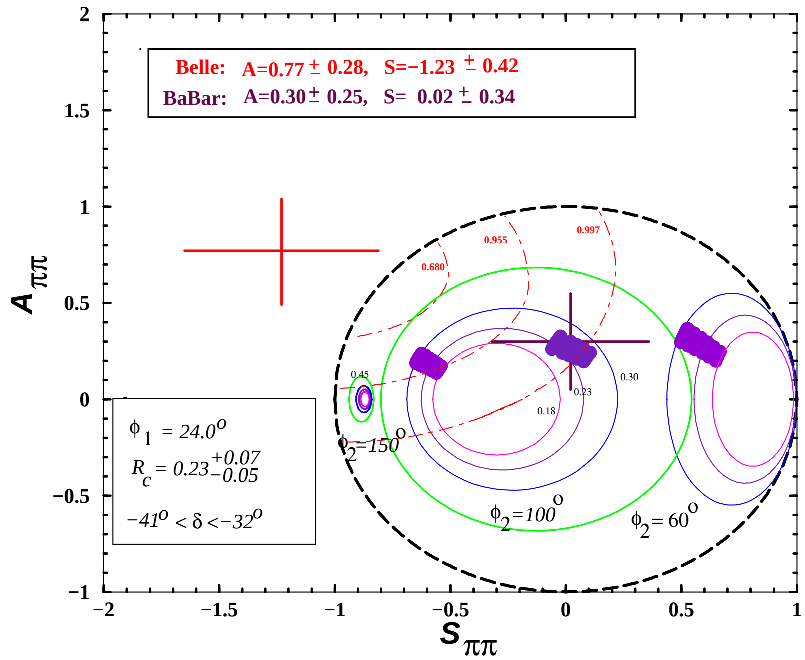


FIG. 3: Plot of $A_{\pi\pi}$ versus $S_{\pi\pi}$ for various values of ϕ_2 with $\phi_1 = 24.3^o$, $0.18 < R_c < 0.30$ and $-41^o < \delta < -32^o$ in the pQCD method.

IV. EXTRACTION OF $\phi_2(=\alpha)$ FROM $B \to \pi^+\pi^-$

Even though isospin analysis of $B \to \pi\pi$ can provide a clean way to determine ϕ_2, it might be difficult in practice because of the small branching ratio of $B^0 \to \pi^0\pi^0$. In reality in order to determine ϕ_2, we can use the time-dependent rate of $B^0(t) \to \pi^+\pi^-$. Since penguin contributions are sizable about 20-30 % of the total amplitude, we expect that direct CP violation can be large if strong phases are different in the tree and penguin diagrams.

In our analysis we use the c-convention. The ratio between penguin and tree amplitudes is $R_c = |P_c/T_c|$ and the strong phase difference between penguin and tree amplitudes $\delta = \delta_P - \delta_T$. The time-dependent asymmetry measurement provides two equations for $C_{\pi\pi}$ and $S_{\pi\pi}$ in terms of three unknown variables R_c, δ and ϕ_2[32]. Since pQCD provides us $R_c = 0.23^{+0.07}_{-0.05}$ and $-41^o < \delta < -32^o$, the allowed range of ϕ_2 at present stage is determined as $55^o < \phi_2 < 100^o$ as shown in Figure 3.

According to the power counting rule in the pQCD approach, the factorizable annihilation contribution with large imaginary part becomes subdominant and give a negative strong phase from $-i\pi\delta(k_\perp^2 - x\,M_B^2)$. Therefore we have a relatively large strong phase in contrast to QCD-factorization ($\delta \sim 0^o$) and predict large direct CP violation effect in $B^0 \to \pi^+\pi^-$ with $A_{cp}(B^0 \to \pi^+\pi^-) = (23 \pm 7)\%$, which will be tested by more precise experimental measurement within two years.

In the numerical analysis, since the data by Belle collaboration[33] is located ourside allowed physical regions, we considered the recent BaBar measurement[34] with 90% C.L. interval taking into account the systematic errors:

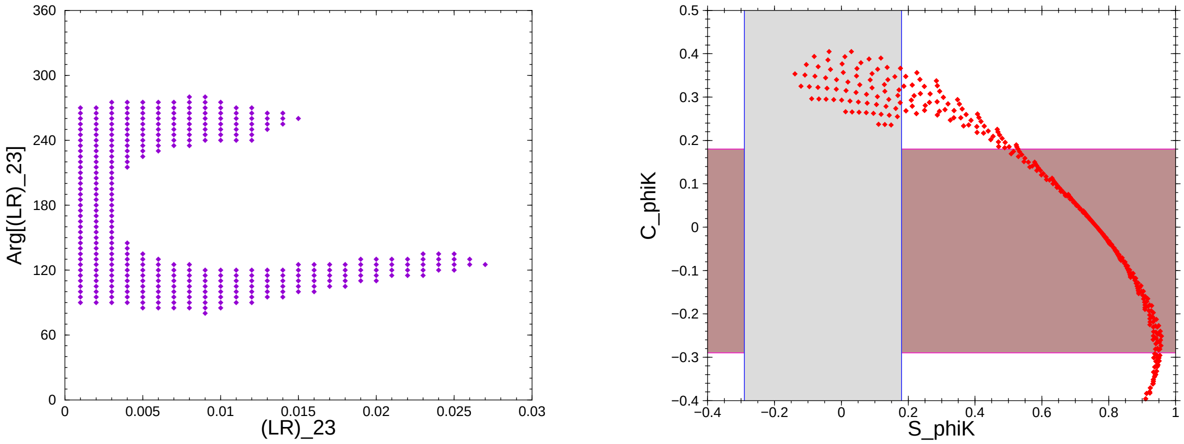
- $S_{\pi\pi} = 0.02 \pm 0.34 \pm 0.05$ [-0.54, +0.58]
- $A_{\pi\pi} = 0.30 \pm 0.25 \pm 0.04$ [-0.72, +0.12].

The central point of BaBar data corresponds to $\phi_2 = 78^o$ in the pQCD method. Even if the data by Belle collaboration[33] is located ourside allowed physical regions, we can have allowed ranges with 2 σ bounds, but large negative δ and $R_c > 0.4$ is prefered[35].

V. NEW PHYSICS SEARCH IN $B \to \phi K_s$ DECAYS

In SM the time-dependent CP asymmetry in $B \to \phi K_s$ is expected the same as one in $B \to J/\psi K_s$, $sin(2\phi_1)(J/\psi K_s) = 0.734 \pm 0.054$. Recently Belle measured $S_{\phi K_s} = -0.96 \pm 0.50^{+0.09}_{-0.11}$[36] and BaBar obtained

FIG. 4: Allowed ranges of $(\Delta_{LR})_{23}$ and plot of the correlation between $S_{\phi K_s}$ and $C_{\phi K_s}$



$0.45 \pm 0.43 \pm 0.07$[37]. The world averaged value -0.15 ± 0.33 with 2.7 σ deviation from SM prediction shows large possibilities of new physics contributions in the decay amplitue of $B \to \phi K_s$ though the quantum loop effect. We consider the new physics contribution of gluino mediation SUSY in the MSSM. Among four possible contributions (LL, RR, LR and RL-insertions), the LR and RL-contributions can be dominant, while the LL and RR-contribution are suppressed strongly from $B_s - \bar{B}_s$ mixing. Here we show the results of LR-insertion within PQCD approach including vertex corrections. In this case, the analysis can be consistent because the amplitudes of SM and new physics part keeps upto $0(\alpha_s^2)$ terms in the short distance part.

In our numerical analysis we used the following constraints:

- $2.0 \times 10^{-4} < Br(b \to s\gamma) < 4.5 \times 10^{-4}$, $\quad -27\% < A_{cp}(b \to s\gamma) < 10\%$,
- $Br(B^0 \to X_s l^+ l^-) = (6.1 \pm 1.4 \pm 1.3) \times 10^{-6}$, $\quad \Delta M_s > 14.4 ps^{-1}$.

In LR-insertion case, C_{8g} contributions can be important both for the branching ratio and the CP-asymmetry and the most strong constraint comes from $Br(B \to X_s\gamma)$. As shown in figure 4, $S_{\phi Ks}$ can be reach to -20% and $C_{\phi Ks} < 40\%$. The detail analysis will appear elsewhere[38].

VI. SUMMARY AND OUTLOOK

In this talk we have discussed ingredients of PQCD approach and some important theoretical issues with numerical results by comparing exparimental data. The PQCD factorization approach provides a useful theoretical framework for a systematic analysis on non-leptonic two-body B-meson decays including radiative decays. Our results are in a good agreement with experimental data. Specially pQCD predicted large direct CP asymmetries in $B^0 \to \pi^+\pi^-, K^+\pi^-$ decays, which will be a crucial touch stone to distinguish our approach from others in future precise measurement. Recently the measurement of the direct CP asymmetry in $B \to K^{\pm}\pi^{\mp}$, $A_{cp}(K^+\pi^-) = -9 \pm 3\%$ is in accordance with our prediction. For other decay modes, for instance $B \to D^{(*)}\pi$[39], H.N.Li has summarized it in this conference.

We discussed the method to determine weak phases ϕ_2 within the pQCD approach through Time-dependent asymmetries in $B^0 \to \pi^+\pi^-$. We get interesting bounds on $55^o < \phi_2 < 100^o$ with 90% C.L. of the recent BaBar measurement.

For the time-dependent CP-asymmetry of $B \to \phi K_s$, we also explore the possibility of the new physics contributions from gluino mediation SUSY in MSSM.

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